

P-8A “Poseidon” Collaborative Simulation and Stimulation for Electromagnetic Environmental Effects Test & Evaluation

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Over the past several decades, technological advances have provided the Naval Air Systems Command (NAVAIR) with exciting opportunities while creating significant challenges to those who design, test, and operate the complex mission systems found on today's war-fighting aircraft. The responses to these challenges are well underway and began with innovative planning and cost-wise construction of various next-generation facilities, conceptual planning of integrated and extensible network infrastructures, and the insistence on collaborative engineering across all phases of the acquisition life cycle. Today, the challenge continues and, in many aspects, has become even more difficult, stretching our fiscal, technological, and personnel resources to their limits. This article addresses one of the more difficult aspects of today's challenges: Conducting Ground-Based Full Spectrum Test & Evaluation on Next-Generation Systems.

Key words: advanced test facilities; complex operational systems; electromagnetic compatibility; electromagnetic environmental effects (E³); network-centric warfare; realistic mission environments; simulator/stimulator testing labs.

The Naval Air Systems Command (NAVAIR) has many robust, state-of-the-art test and evaluation (T&E) facilities that evaluate entire systems before significant decisions are made to deliver some of the world's most advanced weapons systems into the hands of our sailors and marines. Advanced Installed Systems Test Facilities, managed and operated by the Integrated Battlespace Simulation and Test (IBST) Department, provide realistic ground-based test environments during various phases of systems development to identify and reduce risks prior to more costly and rigorous flight-test phases. A multitude of potential risks associated with overall system performance, personnel safety, and intra-system electromagnetic compatibility are identified during all phases of system development in a scientifically-controlled environment through the use of advanced

simulation and stimulation techniques. Test results provide critical data to developers and program managers well before important program milestone decisions, and provide insight into how our next-generation systems will function in joint and coalition mission threads and future battle space environments. Facilities, such as the Air Combat Environment Test and Evaluation Facility (ACETEF), the Surface/Aviation Interoperability Laboratory (SAIL), the Integrated Battlespace Arena, and a variety of advanced electromagnetic environmental effects (E³) facilities were purposely designed to facilitate the immersion of installed systems in an environment that can repeatedly replicate realistic mission environments and provide detailed data to evaluate potential system effectiveness during actual missions. Simulators and stimulators are designed to provide realistic Electronic Warfare (EW) threat environments, authentic Global Positioning System (GPS) satellite signals, friendly and hostile communications and data link signals, and accurate electromagnetic environmental effects in a

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scripted, realistic and cohesive test event that replicates any level of detail desired. Central to these test events are models, such as the Joint Integrated Mission Model (JIMM) and the Next Generation Threat System, that “set the stage” and drive computer simulations and facility stimulator hardware, sharing necessary data through standardized interfaces. From single-threaded, focused test vignettes to fully integrated wartime scenarios, the laboratories and facilities in NAVAIR are capable of emulating a wide range of realistic environments in a live, virtual, or constructive manner. As Major Range Test Facility Base (MRTFB) unique national assets, these advanced capabilities support NAVAIR and U.S. Navy testing, but are also available to support all joint-service programs.

A central component of advanced ground test capability, the Advanced Systems Integration Laboratory (ASIL) is a radio frequency (RF) - shielded anechoic chamber measuring 180' × 180' × 60' with over one-hundred-thousand square feet of RF-absorbing material. This chamber provides “the stage” for some of the most advanced test laboratories, distributed simulation and stimulation hardware and software, and fully integrated aircraft and facility instrumentation components. The resulting simulated environment is capable of providing test articles with virtual, scripted mission scenarios that provide flight-like realism to test the complex suite of communication, navigation, identification, and mission systems.

As the complexity of tomorrow's systems increases, so does the requirement for research, development, and test and evaluation facilities to provide matching levels of complexity to produce realistic testing environments. Advanced weapons systems, such as the P-8A “Poseidon” and the F-35 “Lightning II” boast unparalleled intra-system workings and will demand integrated testing methodologies never before imagined. To illustrate the challenges and their potential solutions, we look at the early stages of test planning for the P-8A “Poseidon,” focusing on the new complexity required for what was once straightforward E³ testing.

Advanced electromagnetic compatibility testing for next-generation multi-mission maritime aircraft

The P-8A “Poseidon” Multi-Mission Maritime Aircraft will become the newest addition to the U.S. Navy's airborne surveillance and reconnaissance arsenal, bringing unparalleled capabilities and complexities to the future of naval aviation (*Figure 1*). A cornerstone of the Navy's ongoing transformation in naval war-fighting doctrine, the P-8A brings forward-looking operational concepts of jointness, interopera-



Figure 1. P-8A “Poseidon”

ability, and full-spectrum dominance of sea-, air-, space-, and information-domains to its primary mission.

Keys to achieving full spectrum dominance are information superiority and operations, through the application of network-centric warfare. Information, information-processing, and communications networks provide the core of every military activity, and sharing this information seamlessly through robust communication networks that provide common operational and tactical pictures to naval commanders is crucial to the Navy's effectiveness in supporting national interests. The P-8A will be a major airborne asset providing intelligence, surveillance, and reconnaissance information; information processing; and communications in network-centric warfare.

Testing advanced systems

The challenges of testing such a complex collection of systems and subsystems are daunting, considering the interdependencies and interrelationships of each of the aircraft's mission systems. These challenges are combined with rigorous intrasystem electromagnetic compatibility (EMC) compliance requirements (Military Standard MIL-STD-464A 2002) and will demand a great deal of collaboration and coordination among and across organizational boundaries, facilities, and test phases. This level of integrated testing is the reason NAVAIR needs such advanced T&E facilities, and while the facility's architecture can provide critical tools, the collaboration of the facility's workforce becomes equally critical to meaningful testing.

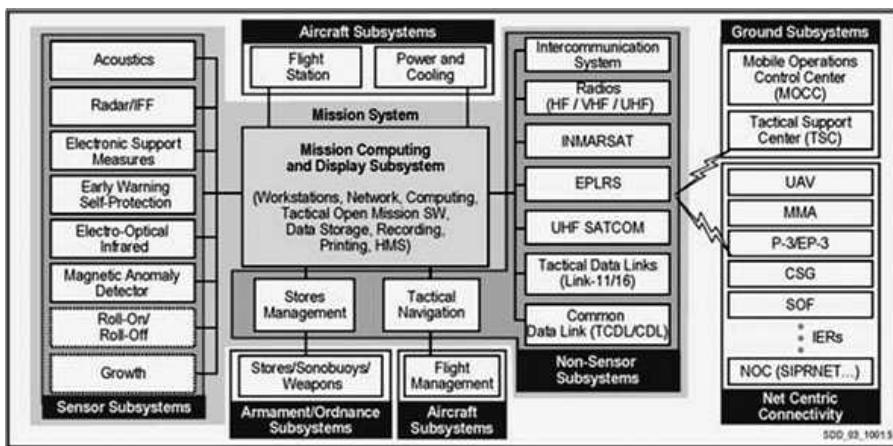


Figure 2. Mission computing and display system

The P-8A's operational environment will be a complex and adaptive blend of sensors, shooters, Command and Control assets and data links; in essence, a collection of nested systems and subsystems operating in unison. To properly test the effectiveness of such advanced weapons systems, the entire aircraft must be stimulated as it would be in an actual mission environment. Stimulating only a few mission systems leaves the remainder of the aircraft's integrated systems in a static state and represents unrealistic mission profiles. Stimulating only a portion of the mission systems also allows little chance of identifying adverse electromagnetic interactions.

As an example, the Mission Computing and Display System (MCDS) (Figure 2) requires a blended GPS and Air Data Inertial Reference Unit's (ADIRU) input for proper operation. The GPS/ADIRU can be energized, but without stimulating these systems with valid signals and data, the GPS will "search the skies" and be unable to calculate a position. The GPS receivers must have valid satellite and positional data that agrees with the latitude and longitude entered into the ADIRU;

anything less will result in immediate ambiguities within the overall P-8A navigation system with unforeseeable complications for the MCDS and mission systems.

Various stimulators and simulators are required to exercise systems like those on the P-8A. In facilities like the ACETEF, many advanced electronic combat stimulation capabilities are co-located with the chambers and test assets, while others can be remotely networked to support testing. For example, the SAIL has remote connections via fiber optics to provide acoustic and RF ship data links to aircraft under test. Other Joint Service capabilities can be linked and utilized as needed. The table below lists some of the facility's current capabilities (*Table 1*).

IBST simulators, stimulators, and laboratories are integrated into a single virtual dynamic environment using JIMM. JIMM becomes the executive run-time controller for the integrated assets and provides controlled parallel simulation events, using advanced multi-threading processes, to maintain a fully repeatable ordering of events to all interfaced stimulators. The aircraft data bus is instrumented and the data flow

Table 1. IBST simulation/stimulation laboratories supporting the P-8A test

Simulator/stimulator/lab	Purpose
Automated Identification Friend or Foe (IFF) Test Set	Simulates the SIF modes 1, 2, 3, C, and 4; two operating modes; interrogation mode; and transponder mode.
Multiple Link Test and Training Tool	Full network simulation of Link 11 and 16 data links has the capability to simulate any combination of tactical digital information links simultaneously.
Strategic Data Link System (SDLS)	A multi-channel UHF satellite communications (SATCOM)/line-of-sight radio system.
GPS Test Equipment (GPS/SPIRENT)	Simulates a constellation of up to 12 satellites in both L1 and L2; the system under test can be placed anywhere and at any time.
Advanced Multiple Environment Simulator (AMES) III	A dynamic RF threat simulator capable of generating complex radar threat environments.
Infrared Sensor Stimulator	Designed to support the design, development, integration, and testing of infrared electro-optical sensor systems.
Joint Communications Simulator (JCS)	Produces motion, range, and direction of arrival for hundreds of independent high fidelity CNI emitters.
Surface/Aviation Interoperability Lab (SAIL)	Provides tactical common data link and multiple sonobuoy signals.

is time-tagged and captured to provide before-and-after comparison of data processed by the P-8A. This continual real-time feedback allows for detailed post-test analysis of obvious and not-so-obvious adverse intrasystem EMC interactions. In this manner, an intrasystem EMC test of the P-8A can be efficiently conducted while the mission systems and subsystems are artificially immersed in “virtual flight” with relevance to anticipated operational missions.

In order to achieve flight-like realism and mission relevance, JIMM is programmed to run pre-scripted warfare “scenarios” which, for the purpose of this article, refers to the textual depiction of P-8A crew actions, system functions, external activities or stimuli, and all preconditions in the course of accomplishing a whole or partial mission. Scenarios are based on actual Operational Situations and Tactical Situations (TAC-SIT) as defined in the P-8A Scenario Development Strategy, 2006 (Scenario Development Strategy 13126/A1J1B/PMA-290/SE/1053 2006); the same Operational Situations and TAC-SITs used for systems integration and crew training in the P-8A’s Systems Integration Laboratory (SIL). In practice, the missions conducted inside an actual P-8A aircraft in the ASIL will mimic previous missions that have been rehearsed in the P-8A SIL.

To illustrate how a portion of the intrasystem EMC testing will be performed in relation to these scenarios, TAC-SIT 5-4, a hypothetical search and rescue mission will be utilized. But, before this search and rescue mission is conducted, EMC engineers will create an appropriate “communications plan” within TAC-SIT 5-4 to satisfy one of the more critical facets of these tests; to evaluate RF interference between all P-8A transmitters and receivers. EMC engineers use a standalone internally developed software tool called Prediction of Intra-system EMC to help predict where RF interference will be at its worst. This is a mathematical analysis and prediction program that is used in advance of testing to predetermine most likely RF interference combinations.

The Prediction of Intra-system EMC program makes the assumption that all receivers and transmitters are potential victims and sources of interference against one another and properly lists all frequency combinations where interference is likely. These predetermined “worst case” frequency combinations are written into TAC-SIT 5-4 as part of the detailed communication plan. This mission scenario involves take off, climb out, transit to an operating area, coordination of rescue efforts with Navy surface assets, and electronic surveillance measures to keep track of unfriendly forces. Mission system avionics use involves line-of-sight communications with encryption, various

data link operations, identification friend or foe, shipboard automatic information system, geo-locating targets with the electro-optical/infrared turret, inverse synthetic-aperture radar, and electronic surveillance measures. This four-hour mission scenario is flown over hostile littoral waters and concludes with the P-8A returning home safely.

Intrasytem EMC tests in the ASIL will be concentrated on the integrated P-8A mission systems. Since a single source/victim test matrix listing the individual mission system components would be too difficult to manage, tests will be parsed into smaller more manageable matrices using a layered approach to test the whole mission system. Equipment such as line-of-sight communications, satellite communications, identification friend or foe, radar, navigation, sensors, MCDS, weapons systems, etc. will be logically grouped into smaller matrices with a goal of (x) number of victim/source tests per hour or per scenario run. Each scenario-driven test event is intended to allow for a manageable, but thorough evaluation of a small number of systems and subsystems rather than risk the potential chaos of doing too much at one time. In this manner, individual system-versus-system will be scrutinized for adverse EMC, while building up to and ultimately achieving 100 percent-versus-100 percent operation of the whole aircraft and mission systems suite. We find it critical that EMC test engineers and scenario developers collaborate continually to ensure mission scenarios match EMC test requirements. For all P-8A tests, attempts will be made to use pre-existing TAC-SIT scenarios. These scenarios or vignettes can be modified in accordance with the P-8A Scenario Development Strategy 13126/A1J1B/PMA-290/SE/1053 (2006) to satisfy the EMC test requirements.

From an intra-system EMC perspective, all receivers and transmitters can be evaluated in this manner, along with search and rescue mission systems and subsystems. The hypothetical TAC-SIT 5-4 scenario includes elements critical to the intra-system EMC evaluation which are modifiable, yet can run as many times as necessary until one of the previously mentioned victim/source test matrices is complete. Minor changes to the detailed communication plan in the TAC-SIT will blend the software tools of the EMC engineering discipline with the modeling and simulation tools of IBST. This allows a thorough EMC evaluation of the integrated P-8A systems and subsystems with relevance to the aircraft’s intended mission. Advanced EMC cannot neglect the air/surface integration challenges nor ignore crucial joint interoperability issues. As programs evolve and plan for joint interoperability and net-ready Key Performance Pa-

rameter, E³ and mission system performance testing will evolve as well.

Conclusion

Creating operationally relevant test scenarios in a controlled environment is necessary to accomplish effective and affordable testing on the extremely complex weapons systems of tomorrow. The P-8A may be one of the first “next generation” systems to undergo testing in such an environment, but will be followed by a surge of advanced programs in an increasingly difficult and demanding T&E world. The MRTFB, T&E communities, and NAVAIR have taken proactive steps by creating the framework for full-system collaborative and cooperative testing and are poised to take these concepts further as integrated systems advance. For programs like the P-8A, we are learning to leverage simulation expertise, tools, and facilities across test phases. Collaboration between E³/EMC test engineers and flight/ground test engineers reduces cost by sharing simulation and stimulation assets and using common test methodologies. Significant schedule improvements can also be realized by conducting tests concurrently. These types of advanced ground tests have proven to reduce risk for programs and platforms undergoing developmental and operational tests. The ability to transition from ground-to-flight test with the confidence that all systems work as expected, that interoperability in stressing missions is assured, and that mission crews have fully rehearsed missions is key to efficient and cost-effective execution. With the facilities, laboratories, and simulators in place, the next challenge is to continue to strengthen working relationships and collaboration between Systems Engineering, Modeling & Simulation, Analysis, Training, and T&E communities, as well as strengthening interfaces with the commercial developers of tomorrow’s weapons systems. The path to the future of a usable Joint Mission Environment for all phases of testing begins with small steps and innovative thought. For programs like P-8A and others, the process has

begun and collaborative facilities and infrastructure are critical to future success. □

PAUL ACHTELLIK served in the U.S. Navy from 1968–1980 as an aviation electrician prior to his present involvement with electromagnetic compatibility (EMC) T&E. He's now a senior member of the EMC Branch within the Integrated Battle Space Simulation and Test Department at the Naval Air Warfare Center Aircraft Division, Patuxent River, MD. The EMC branch is responsible for conducting electromagnetic environmental effects (E3) tests on U.S. Navy aircraft, other DOD aircraft and similar full scale integrated systems. With 27 years of “hands on” experience, he's participated in over 150 E3 tests on a wide variety of aircraft and has covered all aspects of E3 T&E including; EMC, EMV, P-Static, Lightning, ESD, EMP, and EMI evaluations. Paul is Narte Certified in E3 and considered a “subject matter expert” in his field. He currently serves as E3 project lead and manager for all P-3 type aircraft, Unmanned Aerial Systems and the Navy's new P-8A aircraft. The complexity of hardware, software, and C4ISR intra/interoperability within these new aircraft systems cannot be understated. Advanced systems of systems are data driven and require complex inputs to determine if they are working correctly. Paul's E3 test methodology has evolved to meet this challenge, where, the future of testing requires a shift to “Operationally Relevant” test environments to accomplish E3 T&E effectively and affordably. E-mail: paul.achtellik@navy.mil

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